A preliminary insight of pedestrian avoidance behavior effect on pre-impact pose

Shi Shang, Quan Li, Bingbing Nie*, Guibing Li, Qing Zhou, Catherine Masson, Pierre-Jean Arnoux, Max Py, Ciaran K. Simms

I. INTRODUCTION

Road traffic injury remains a global health issue. Pedestrians account for 23% of the fatalities in motor vehicle accidents each year, namely 310,000 approximately [1]. Many researchers have been working on pedestrian kinematics and injury mechanisms with various methods such as real-world crash video analysis, cadaver tests, numerical study, and recently also virtual-reality-based volunteering experiments [2-5]. However, the pre-impact poses of pedestrians in both cadaver tests and FE/MB platforms are usually set as an ordinary static standing or static walking posture due to staged test limitations and less focus is given to the pedestrian avoidance behavior effect. In fact, pedestrians might notice the vehicle and use active behavior to avoid the impending conflict in the real world, resulting in variable pre-impact poses [3]. The rotation of the pedestrian at impact and the contact injury will be changed due to the chain reaction. The current study aims to indicate and quantify the kinematics differences between cadavers and pedestrians *in vivo* in vehicle impacts.

II. METHODS

A total of 33 vehicle-pedestrian impact videos selected and downloaded from Youtube, Youku, and China road CCTVs are studied and analysed to obtain a general understanding of the pre-impact poses the pedestrians exhibited. In parallel, six cadaver tests recorded by high-speed cameras are utilized as references. Finally, a group of marker-based VR volunteering tests [3] provided information on pedestrian pre-impact kinematics as a consequence of natural avoidance behavior. Joint angles, human velocity and accelerations were captured by inverse kinematics approaches using Opensim. The setups and methods applied in the cadaver tests and the volunteering experiments are presented in previous research [2, 3] in detail.

III. INITIAL FINDINGS

In the real-world videos, the common collision scenarios involved cases in which the pedestrian suddenly emerged into the vehicle lane and was impacted by the vehicle or a vehicle was turning left/right at the crossroads and hit the pedestrian. In 17 of 33 cases there was evidence that the pedestrian noticed the vehicle and exhibited reactions such as standing still, stepping back, accelerating, stooping backward, pushing the bonnet. Specifically, pedestrian active avoidance behaviors extracted from VR-based crash scenarios are classified into three distinct groups: forward avoidance, backward avoidance and oblique stepping. In contrast, standing still was observed in real-world crashes, but not in the volunteer tests [3], see Fig 1. Despite the reactions that pedestrians made as in conscious response to the pending danger, the pedestrian failed to notice the upcoming vehicle and then the collision occurred in both real-world and virtual environments.

.

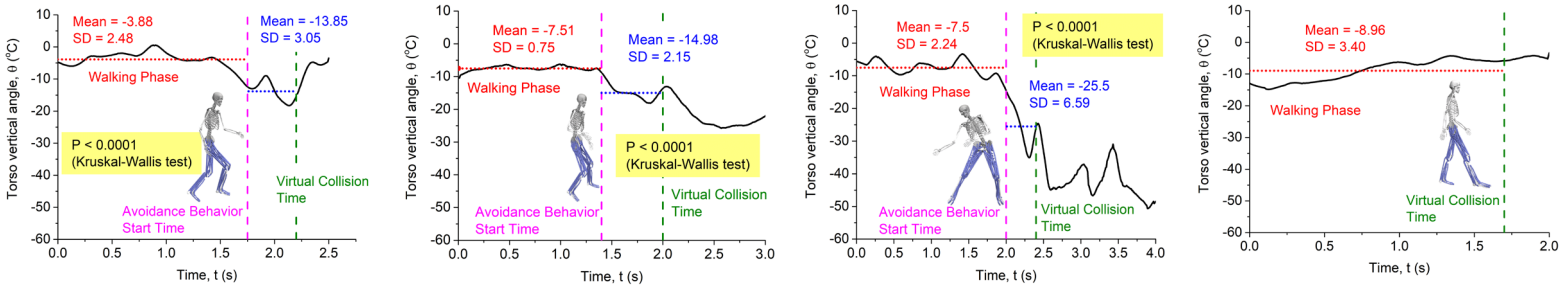
A remarkable feature of the pre-impact avoiding pose pedestrians showed in real-world crashes and volunteering tests is the changing vertical angle of the human torso. During normal walking, the torso usually maintains a more or less upright (vertical). However, once the pedestrian realized the danger and exhibited various avoidance behaviors by accelerating, decelerating, stepping back, etc, the vertical angle of the torso is subject to variation. Thus, the torso angles were measured based on the VR-based volunteer experiments to quantify the kinematic differences among typical groups of pedestrian pre-impact poses. The preliminary comparisons of torso angles in different pose categories (forward avoidance, backward avoidance, oblique stepping, and normal walking) are shown in Fig. 2. Results of Kruskal-Wallis tests show that the torso angles of pedestrians are substantially different during avoidance behavior compared with the pose during normal walking (P-value < 0.0001).

B. Nie (e-mail: nbb@tsinghua.edu.cn; tel: +86-10-6278-8689) is an Associate Professor, S. Shang is a Research Associate, Q. Zhou is a Professor and Q. Li is a PhD student in School of Vehicle and Mobility at Tsinghua University, China. G. Li is an Associate Professor in School of Mechanical Engineering at Hunan University of Science and Technology, China. P-J Arnoux and C. Masson are Senior Researchers and M. Py is Assistant Engineers at Laboratoire de Biomecanique Appliquée, Aix-Marseille Université, France. C. K. Simms is an Associate Professor in Biomechanics at Trinity College Dublin, Ireland.

(a) Representative avoiding poses of pedestrians observed from real-world crashes and VR-based volunteering experiments

(b) Pre-impact poses in cadaver tests

Fig. 1. Examples of pre-impact pose from different car-pedestrian collision scenarios



(a) Forward avoidance (b) Backward avoidance (c) Oblique stepping (d) Normal walking

Fig. 2. Time-histories of pedestrian torso vertical angle in different reaction scenarios

IV. DISCUSSION

An overview of the pedestrian kinematics in real-world crashes and virtual experiments indicates the pre-impact pose diversity and unpredictability, far beyond the setup in current staged physical and computational tests. The small sample size is a limitation of this study while it is evident that pedestrian active behavior plays a vital role and leads to the difference in kinematics. The torso vertical angle has a considerable change (7.47 to 18 degrees) from normal walking phase to an avoiding phase. The altered torso angle necessarily changes the head position and the post-impact kinematics as well as the injury risk might be affected as a chain reaction. This study will be extended to analyse: a) the effect of pedestrian avoidance behavior on post-impact kinematics, injury risk and severity (which could be beneficial to build future pedestrian injury databank for injury prediction; b) whether there is a relationship between vehicle front-end parameter (especially BLEH/hip height) and pedestrian post-impact rotation angle before landing.

V. ACKNOWLEDGEMENTS

This work was in part supported by National Natural Science Foundation of China (52072216, 51705276), and Tsinghua-Toyota Joint Research Fund.

VI. REFERENCES

[1] WHO. 2018.
[2] Shang, S., *et al.*, Saf. Sci., 2020
[3] Nie, B., *et al.*, Sci. Rep., 2021
[4] Li, G., *et al.*, Traffic Inj. Prev., 2016
[5] Han, Y., *et al.*, Int. J. Crashworthiness., 2019